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Semantic Technologies and Semantically Defined "Building Information"

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***Abstract*—The need for knowledge management in the BIM environment has been finalized by a proposal of taxonomy, including the structure and form of a proposal describing the competencies of individuals, teams, groups and organizations. It has shown that the basic output of the current investigations is the need to consolidate the knowledge structure in the BIM environment. On the basis of further research of the literature, organizational behavior and individual education schemes, several matrix enumerations describing the general form of human beings as knowledge bearers and derived competences were created as a necessary prerequisite for all activities related to the manipulation of knowledge. Therefore descriptions of the competence of individuals in the form of competencies how to use the appropriate knowledge have also been identified**.

Keywords—building information management, semantics, taxonomy, competencies construction

I. INTRODUCTION

Preliminary research presented here has been focused on exploration basic possibilities, how to improve and settle inter-generation and also inter-experience communication and sharing resulting knowledge for improving processes within emerging knowledge-based organizations. In spite of working with hard data stored in computers and project protocols, it was clear, we need to focus on semantics of all entities and elements more than on their syntax.

In the semantic site environment, ontologies will be used to define concepts and relationships between concepts in a given domain. Knowledgebase is an information warehouse created over ontology to collect, edit, and share information. Computer applications that use semantically-defined information must first import ontologies that define data and become aware of how the data are organized. The Semantic Web provides distributed knowledge base systems that can be easily integrated.

Web services enable computer applications to communicate with each other over the Internet [1]. However, it is clear that these web services have a significant amount of constraints:

1) They provide syntactic interoperability, which requires data to be transmitted in a specific format.
2) The web service interface must not be changed otherwise the application communicating with the service will be disrupted.
3) The content of the messages transmitted by the web service cannot be interpreted by a computer, which prevents any automation using workflow. In order to add semantic content to a web service message, this content must be formally and explicitly conceptualized using ontologies.

To augment the capabilities of web services towards dynamic interoperability, it is necessary to combine the Semantic Web and Web Services technologies to create "Semantic Web Services". Semantic Web Services Technology uses ontology to semantically define web services. This way, you can automate the disclosure of the service, its build and execution.

Several researches have now been carried out in the field of semantic web technology applications for energy management modeling in buildings. E.g. Kofler has designed a "smart home system" that fine-tunes all the energy facilities in the building [2]. The system uses the knowledge base of various energy parameters as well as energy providers to make energy-efficient decisions on behalf of users. Kim et al. [3] developed a semantic system for naming materials that automatically searches for values of material values that then enter the analytic energy management applications in the building.

II. METHODOLOGY

Focus of successive research will be primarily on construction organizations that suffer most in today's boost of digital economy [4]. This preliminary research focused on exploration of complete area of competencies of both individuals and teams within such organization. Methodology started from the point, how to cluster really different and varied competencies into sets, we can work with [5].

The Range of Competencies:

The range of basic competencies within construction industry relates to the individual's capabilities that enable him to perform measurable activities or deliver measurable outputs. Input data and information were selected from Czech and European projects run by CEN (European Committee for Standardization) and ČAS (Czech Agency for Standardization) and were collected into specific circuit. This circuit was divided into the following competency layers:

1) *Basic characteristics* - personality attributes inherited to a person who generally cannot be gained through training or learning. Basic attributes represent individual approach, behavior, motivation and other attributes measurable by psychometric indexes similar to those of the Myers-Briggs Indicators and similar personality

assessment systems. The naturalness of learning with foreign languages, the innate ability to solve complex mathematical problem is example of these characteristics [6].

2) *Situational un-blockers* - personality attributes linked to nationality, mother tongue or similar (culturally) criteria may play a relevant role in the delivery of services or products. E.g. ability to speak a certain language can play a role in certain situations. For situational un-blockers, criteria appropriate to a particular situation may be irrelevant to another.

3) *Qualifications, certificates and licenses holders* - Attributes related to the existence and proven sufficiency of academic education, scientific publications, professional accreditations, skills or professional certificates or licenses. Such qualifications or licenses are measurable and provide sufficient evidence of "existence, acquisition and degree of competence.

4) *Historical indicators* - attributes in relation to the history of employment, project experience (both project types and their size), roles and positions held. Historical indicators provide changing information about a person's past activities and indicate potential abilities in similar future situations. E.g. The role of a BIM manager, held by a particular individual in a construction company for several years, is an indicator of specific competencies in the construction - a specific part of BIM management [7].

The four primary competencies represent individual professional competences, broken down into the four types:

a. *Managerial:* ability to make decisions that support the selection or adoption of long-term strategies and initiatives. Managerial competencies include leadership, strategic planning, organizational management [8], (such as "the ability to understand the business benefits and risks of managing BIM processes and workflows" is a competency item within the strategic planning of competency topics within the Managerial Competence Assembly);

b. *Functional:* Non-technical, general skills required when starting a new project. Functional competences include collaboration, start-up, project management, etc. (e.g. the ability to launch and manage a BIM meeting for multiple stakeholders);

c. *Technical:* the individual skills required to generate project outputs through disciplines and specializations. Technical disciplines include modeling, designing, working with model projects and situations, as well as managing the execution of a building using a model as a project [9]. (e.g. the ability to use SW tools to create a precise, error-free model, or the use of SW tools as an essential foundation for building process management);

d. *Supportive:* These competences are the ability and the art of maintaining information and communication technologies and their systems. They include ICT support, HW maintenance, SW maintenance and error support, etc. (e.0g. ability to assist others, SW and HW problems, information sharing, Cloud storage, etc.)

Four secondary competences represent individual auxiliary professional skills. They are:

a. *Administrative:* activities required to achieve and protect organization objectives. Administrative competences include the art of announcing competitions and purchasing services and products, contract management and human resources management (such as the ability to establish the necessary metrics to measure the financial performance of BIM projects);

b. *Operational:* the practices and efforts required for project work or integral parts of the project. Operational competencies include designing, performing analyzes, simulations, calculations, building management, communication with vendors through shared databases (e.g. the ability to use the budgeting model and building schedule);

c. *Implementation:* the ability or the skill to implement transformational concepts and tools into the organization's life (revolutionary and evolutionary). Implementation competences include change management, reengineering, standardization, and introduction of new procedures for job descriptions and internal regulations;

d. *Research and development:* activities requiring the evaluation of existing processes, exploring new solutions and promoting their implementation in practice in organizations or across the sector. R & D competencies include change management, knowledge engineering, research, coaching, etc. (e.g. the ability to monitor, select and recommend technology solutions that are appropriate to expand organizational performance and outputs).

III. RESULTS

Methodology of Sharing Competencies" (MSC) is the major output of this preliminary research. The aim of the motivation activities is to convince the management of organization to improve the competence of employees through intergenerational or inter-experience sharing. Company leadership should understand and accept approach leading to increase their productivity in the company and improve the motivation of employees without incurring extra costs for further training of employees [10]. Furthermore, it is convinced that the MSC has a wider scope and can help them to address other areas of the company's functioning. A typical example is the positive effect of using this methodology when changing corporate culture, etc. Also, it became obvious that creating new taxonomy and ontology based on specific objects and properties used in construction industry should be the way forward and subject of consequent research.

BIM ontology will be a semi-structured domain ontology whose mission will be the acquisition and communication of knowledge among people. It intends to represent the push / pull relationships between BIM participants in different processes, their contributions to processes and their requirements. The proposal to use BIM Ontology in the entire knowledge management process in the BIM Framework is illustrated in Fig. 1.

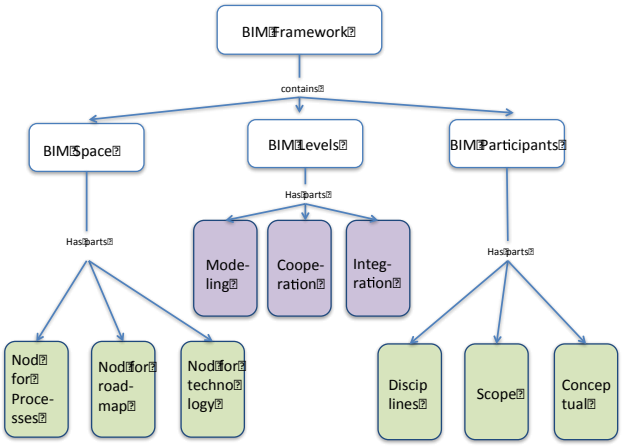

Fig. 1. Taxonomy of BIM Framework, representing BIM ontology (Own design). *(source: authors)*

Taxonomies seem to be an effective and efficient way to organize and consolidate knowledge. A well-structured taxonomy allows for meaningful clustering of experience and is a means leading to more goals, one of which is to provide direction and / or lead to expansion or generalization of knowledge. When developing a specialized taxonomy for the organization of BIM competencies, it is advisable to adopt the guidance suggested by Gregor [11], we expect the taxonomy to be "complex and exhaustive; [includes] classes that include all the phenomena of our interest; [is based on] decision-making rules; [which are] simple and scrambles in class assignment; and classes should be exclusive to each other". Moreover, because taxonomies are designed to help human understanding, [these classes should be] easy to understand and seem to be natural.

BIM ontology contains specific concepts, their relationships and attributes facilitating analytics over domain knowledge to enable the acquisition and communication of knowledge. It also appears that ontological relationships facilitate a "conceptual mixture" created by the interconnection of different types of conceptual constructs: framework, models, taxonomy, classification, and specialized terms from BIM dictionaries.

Proposal of BIM Classification of Competencies, as a Vehicle of Organizational Competencies

Key competencies refer to personality abilities, as opposed to key competencies of an organization. Collective capabilities embedded within the organization create its competitive advantage, customer value, resistance to substitute use, and growth potential – as in [12]. However, since the core competencies of the organization are both "dependent on and incompletely linked to the employees' work competencies and typically represent the "competencies that everyone in society needs" [13], part of the competencies organization is shaped by key employee capabilities.

The domain of competences refers to the individual's professional abilities, the means they use to perform multiple tasks, and the methods they use for their work, which is characterized by complexity in the requirements. Under this heading, we can identify 8 competency layers. There are 4 primary (managerial, functional, technical and supportive), representing the main features of managerial skills and 4 secondary (administrative, operational, implementation and research) that identify those abilities that are formed by the mutual overlap of primary competencies (Fig. 2.).

Proposal of Competencies into BIM Circuit

Competencies as hierarchically organized into circles, layers, and specific focus and are complementary to each other. This means that every individual involved in the implementation of a project in order to carry out specific activities must have a certain mix of competencies in general across all the ranges. E.g. in adding to knowledge of computational methods, the analyst must be able to efficiently generate and exchange data rich 3D models with the architect and other design participants, and must have basic engineering expertise and qualification in working with BIM (knowledge of how to cooperate, data exchange protocol requirements) and implementation competencies (the art of using data exchange tools).

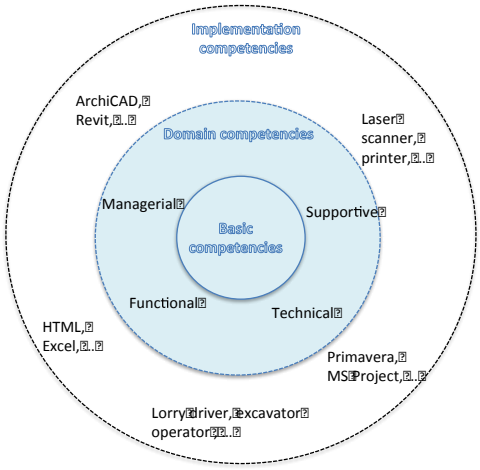

Fig. 2. Competence hierarchy model (own design). *(source: authors)*

In addition to this BIM hierarchy of competencies, it is possible to organize the basic skeleton of BIM competencies, supplementary classification criteria (competency labels / labels) that can be used concurrently. E.g. Competencies can be labeled as generic or specialized. Generic BIM competencies are equally valid across all disciplines, specializations and roles; while specialized BIM competencies are valid only within a subset of disciplines, specializations, or roles:

An architect (discipline A) creates a 3D spatial model and, for example, for a school building it will require a different set of specialized competences than *analyst (discipline B) or building manager (discipline C)* who will also participate in the project and construction of this school building. On the other hand, all of them will need to know how data is exchanged and how certain requirements are communicated, ie to have these generic competencies.

Everyday activities required by junior *designer (Role A)* to create 3D models or documentation are not the same as those required by the team *manager (Role B)* responsible for coordinating the work of many collaborators. However, they both need to know what standards to apply to the documentation.

Regardless of how we designate competencies, "classification is a meaningful cluster of experience" [14]. Organizing BIM competencies in this way enables a meaningful aggregation of BIM knowledge, skills and experience into a structured file for the initial launch of BIM management (we call it the initial set) that can be used to evaluate performance and improve processes throughout the entire construction industry.

Proposal of Simple Specific BIM Ontology

The use of competencies is an action in relation to the process of using the competency items to manage activities or perform measurable work. There are several ways to access the use of BIM competencies. Competency item can be used to:

a) *creating* a list of tasks for the start of a project or processes (e.g. a step by step cookbook for importing 3D models created by an outside designer working with the model in the next steps), or a project quality control procedure (e.g. list of audit activities for collision analysis in project),
b) *generating* standardized mind maps or topic maps, workflow diagrams, and similar graphical records to explain the BIM implementation project implementation, data exchange (e.g. IFC platform, CCS) and collaboration processes,
c) *preparation* of project requirements for the purpose of purchasing services, e.g. through the use of competency items to form an application for a qualification or a call for tender.

Competence Rating - for Team Building

Competence evaluation is an action that relates to the process of measuring the capabilities of individuals within both academic and professional spheres. From the point of view of the organization, individual competencies such as knowledge, skill, personality traits, the most important resources of a company for solution to knowledge of challenging tasks such as decision making, strategic planning or creative design. These individual competencies (e.g. all employees) may not always be explicit. The availability and scope of each employee's empowerment can be the process of appreciation as explicit, making it easier to find out what people know or direct the needed people to the right ones they know. Such sharing of information will increase organizational productivity as well as individual performance. Assessing competencies not only helps HR professionals in their processes within the organization (e.g. selection of suitable candidates, planning and subsequent planning of HR activities), but also can help to predict performance management project over the range of key performance criteria. Structured competencies allow the generation of learning frameworks based on competency-based learning to measure what participants know or can accomplish in a perfect description.

Sample Model for Using BIM Competencies

There are several ways to use the BIM Domain Competence, as formulated before, and how to create List of Structured Competencies (which has the potential for further expansion).

Acquisition or Creation of Competencies - Use for BIM Education

Acquisition, creating competencies is an action that relates to the learning process through competency items. This is achieved through the deliberate collection of BIM competences in BIM learning modules to be further used in professional growth, in-work training, and lifelong learning. Using the classifications as well as the labeled competencies mentioned above, the learning modules can be designed to the required level of detail to meet the training requirements for the target group, such as students, tradesmen, managers in building organizations, etc. Table 1 shows how the circuits and layers of BIM competencies are used to generate sample BIM learning modules.

Items and competencies can be used - if deliberately collected in BIM training modules - both for gaining and improving individual BIM knowledge and skills. According to Voorhees [15], "each individual competence can be used in many different ways. The challenge is then to determine which competencies can be tied together to help different types of learners with the optimal combination of skills and knowledge needed to leverage specific tasks."

Use of Competencies - in Projects

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TABLE I. BIM TRAINING MODULES, FORMULATED USING THE BIM COMPETENCE TAXONOMY

Course Type	*Teaching modules*	*Target Group*
BIM Basics Fundamentals of Revit modeling (Execution - SW tools - modeling)	Introduction to BIM Concept	All roles and disciplines
BIM Legal Aspects	Specifics of Contracts Using BIM 3D Models as Primary Building Information Sources (Domain - Administration - Contractual Relations	BIM Managers, Senior Technicians
Managing BIM Projects	Managing BIM Project Management Plans (Domain - Functional - Management)	Project managers, Facility managers, Investors, Developers
Team cooperation	Presentation functional bases and understanding of data exchange protocols	BIM managers, Technical workers, Technical managers, Others

Source: Authors

Competency item can be used to:

a) creating a list of tasks for the start of a project or processes (e.g. a step by step cookbook for importing 3D models created by an outside designer working with the model in the next steps), or a project quality control

procedure (e.g. list of audit activities for collision analysis in project)

b) generating standardized mind maps or topic maps, workflow diagrams, and similar graphical records to explain the BIM implementation project implementation, data exchange (e.g. IFC platform, CCS) and collaboration processes,

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Competence evaluation is an action that relates to the process of measuring the capabilities of individuals within both academic and professional spheres. From the point of view of the organization, individual competencies such as knowledge, skill, personality traits, "the most important resources of a company for solution to knowledge of challenging tasks such as decision making, strategic planning or creative design" [16]. These individual competencies (e.g., all employees) may not always be explicit. The availability and scope of each employee's empowerment can be the process of appreciation as explicit, making it "easier to find out what people know or direct the needed people to the right ones they know. Such sharing of information will increase organizational productivity as well as individual performance" [16].

Assessing competencies not only helps HR professionals in their processes within the organization (e.g. selection of suitable candidates, planning and subsequent planning of HR activities), but also can "help to predict performance management project over the range of key performance criteria" [17]. Structured competencies allow the generation of learning frameworks based on competency-based learning to measure what participants know or can accomplish in a perfect description [15].

Three Circuits - Multiple Uses

The three circuits, as shown in Fig. 2. in a three dimensional competency model, show multiple application possibilities when used in conjunction with structured BIM competencies. Depending on the syntax of competencies (i.e. how the competence item is worded) and the intended use, each item will be derived from the competency library (Table 6.7) and can simultaneously support learning, assessment methods and practical applications. Separating the syntax from the BIM item of competence, and thus making it impossible to identify this item as a specific behavioral role, provides the BIM library with such flexibility and adaptability competencies [18].

Taxonomy as a Special BIM Ontology

BIM ontology must be an informal, semi-structured domain ontology, designed to acquire and record knowledge and communication among people. The purpose of ontology is to represent knowledge interactions (based on pressure and stroke) between individual BIM players, their requirements and their outputs of work activities.

IV. Conclusion

Basic conclusion from preliminary research could be described as most companies have a competency framework for their employees based on their key professional knowledge, skills and understanding that enable them to meet their job requirements. A valuation system based on a discussion with their supervisor on performance, further education and the needs of professional and personal development was used. The MSC methodology shows that, in order for work to be performed well, the importance of personal skills and qualities must be perceived alongside professional competencies. The MSC methodology thus brings a new dimension in the management of people and offers a unique tool to take advantage and eliminate the individual's weaknesses, together with the values, attitudes and experiences that affect the employees' view of their work and enable them to perform it.

From individual general competencies, BIM competencies are subsequently derived and identified and a proposal for the gradual development of the specialized taxonomy "BIM Classification of Competencies" is presented. It can be assumed that this taxonomy proposal can well be served in practice, e.g. in the form of a real implementation of its content by a working group.

There is further proposed the division of BIM domain competences into several areas, based on which the internal structure of the BIM dictionary is proposed, from which it is logical to derive the unification of BIM terms not only across all branches of investment construction but also the unification of nomenclatures in the international context. The proposed structure of the vocabulary can thus be other important output from the preliminary research and basis material for subsequent work.

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